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October 30, 2015

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Arizona Corporation Commission
DOCKETED

OCT 30 2015

DOCKETED BY

RE: Arizona Public Service Company
2016 Integrated Resource Plan, Docket No. E-00000V-15-0094
Report on Re-Examination of Load Forecasting

Decision No. 75068, in which the Commission acknowledged APS's 2014 Integrated Resource Plan, requires APS to:

"....include a report on the results of the re-examination of [its] load forecasting techniques on or before October 31, 2015. The reports shall explain the results of the re-examination and how those results will be incorporated into the 2016 load forecast."

Attached please find the Company's report on the re-examination of its load forecasting techniques.

If you have any questions, please feel free to contact me at 602-250-3341.

Sincerely,

Kerri A. Carnes

KC/kr

cc: Parties of Record

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ARIZONA PUBLIC SERVICE COMPANY

Re-examination of APS Load Forecasting Techniques

**In compliance with Decision No. 75068
INTEGRATED RESOURCE PLANNING**

October 30, 2015

aps

RE-EXAMINATION OF APS LOAD FORECASTING TECHNIQUES

In Compliance with Decision No. 75068

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Introduction

Following its review of APS's 2014 IRP, the Commission ordered APS to re-examine its load forecasting techniques.¹ The decision required APS to report on "the results of re-examination and how those results will be incorporated into the 2016 load forecast."² Commission Staff had recommended that "LSEs could be directed to place additional emphasis on the future risks and costs to rate payers for each portfolio presented in its IRP. In particular, LSEs should expand their sensitivity analysis . . . of future load forecasts."³ Ultimately the Commission ordered that TEP and APS "re-examine their respective load-forecasting techniques . . . to ensure that [they're] not forecasting high load growth that is unlikely to occur."⁴ APS has undertaken this requirement as an opportunity to re-evaluate its historical methodologies for forecasting. Based on the re-evaluation, APS plans on adopting a new model of population growth, specifically the net migration portion of population growth, as discussed further in this report.

This report is organized into four areas of discussion: (1) Components of the Load Forecast in the 2014 IRP; (2) Population Growth and Long-term Economic Outlook; (3) Modeling Techniques for Residential Energy Demand/Use per Customer Forecast; and (4) Modeling Techniques for Commercial and Industrial Sector Energy Demand.

The first section, Components of the Load Forecast in the 2014 IRP, provides a detailed description of how the forecast was constructed, with additional explanation provided on the multi-step process required to incorporate past and future energy efficiency (EE) and distributed energy (DE) impacts.

The second section, Population Growth and Long-term Economic Outlook, describes the assumptions underlying the forecast for population growth and the long-term economic outlook, and the framework for developing such a forecast in the future. After reviewing the techniques used to forecast population growth for the 2014 IRP, APS contracted for the development of a new econometric model designed to provide clearer insights into changes in migration patterns based on the age and regional distribution of the population and relative business cycle impacts.

The third section, Modeling Techniques for Residential Energy Demand/Use per Customer Forecast, describes the various modeling techniques used in the construction of the residential sector energy demand forecasts and how APS re-examined its current techniques. Residential energy demand can be forecast using either simple ordinary least squares regression models or detailed appliance-specific end use models. APS currently uses, and will continue to use, the appliance-specific end use model as the base method for this sector, but has tested and will continue to test, the applicability of econometric models.

¹ Decision No. 75068 (May 8, 2015).

² *Id.* at 14-15.

³ *Id.* at 12.

⁴ *Id.* at 14.

The final section, Modeling Techniques for Commercial and Industrial (C&I) Sector Energy Demand, describes the predominant method used in the industry for forecasting the C&I sector, econometric modeling. The C&I sector has a much higher degree of heterogeneity in both building types and end uses employed across the sector and therefore energy demand can be better forecasted using econometric models. The variety of econometric models tested and the selection criteria are described in this section.

1. Components of the Load Forecast in the 2014 IRP

This section provides discussion on the multi-step process required to incorporate past and future energy EE and DE impacts: this includes how residential, commercial and industrial class forecasts are developed prior to the inclusion of the effects and impacts of EE and DE, and then how the forecast is affected after forecasted EE and DE effects are taken into account.

APS's load forecast first utilizes a set of basic components. The residential class energy demand forecast is developed by forecasting residential customer additions and average residential use per customer separately, and the product of the two is the total energy demand for the class. The combined C&I class forecast is developed by forecasting total energy demand for the sector as a function of economic growth, among other factors. These two sectors account for 95% of the total energy demand expected on APS's system. Additional components include the forecast for energy demand from irrigation customers, demand from street lighting, and demand from wholesale customers for whom APS has an obligation to serve. After that, line losses are also added to account for the difference in energy demanded at the customer meter and remote generation resources. The goal of this first step in forecasting is to establish a baseline or reference point prior to including any assumptions regarding future energy demand related to EE and DE. This baseline forecast that excludes those impacts is also called the "business-as-usual" (or BAU) forecast.⁵

After the baseline forecast is developed, the expected impacts from the continuation of the Company's EE programs and the DE requirements are layered into the analysis to forecast the net peak demand and energy amounts that will need to be served by generating resources. By layering the effects of EE and DE, the forecast is essentially reduced by behind the meter customer actions, therefore changing what is required to be served from the grid. In recent years, these subtractions from baseline demand have amounted to more than 100 MW and 500 GWH, annually. It is important to understand that each subsequent baseline forecast will include real EE and DE effects from prior years, not previously included in past baseline forecasts. The baseline forecast should be viewed as one of the initial steps in creating a more complete load forecast.

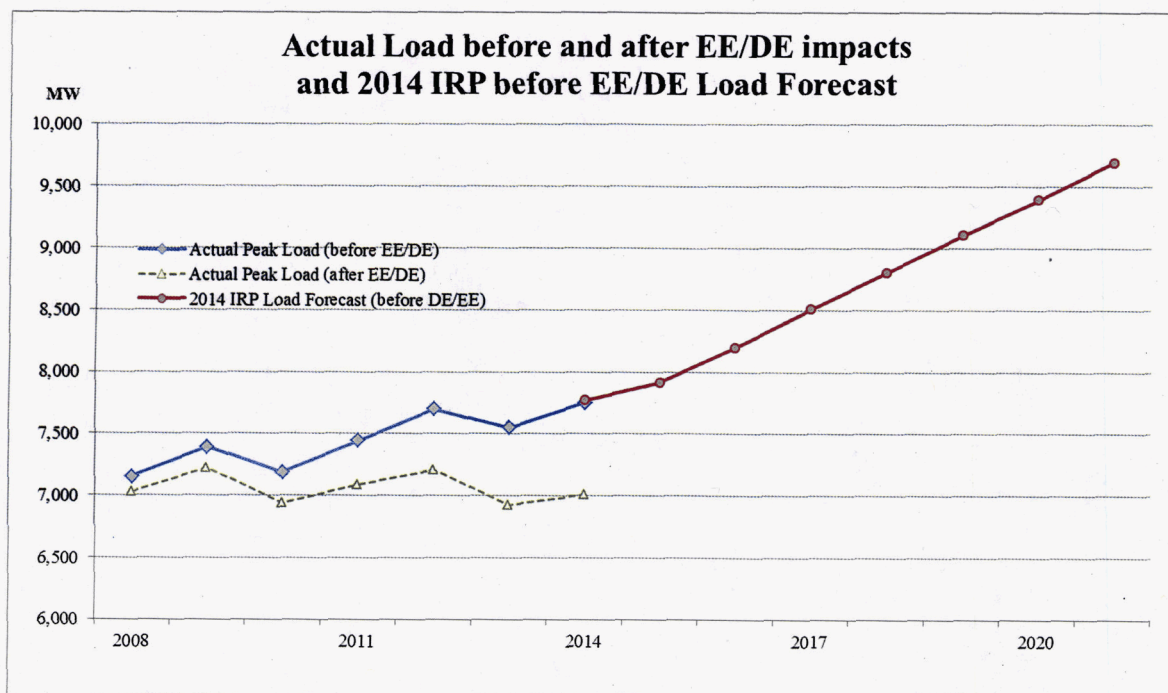
For example, there is a noticeable difference in the 2012 IRP pre EE and DE forecast, which excluded all future EE and DE impacts at the time it was prepared, and the 2014 IRP pre-EE and DE forecast, prepared two years later, which included the EE and DE impacts for 2012 and 2013 that were previously excluded in 2012; this amounted to 240 MW and 1,200

⁵ See APS's 2014 IRP in Docket E-00000V-13-0070 at pages 85-87 for a more complete description of the components and methods that are used in the development of this forecast.

GWH. This difference between the 2014 IRP pre-EE and DE forecast and the 2012 forecast is not due to a forecast change, but rather whether EE and DE amounts for 2012 and 2013 were included. This difference will occur each time an IRP is updated, and will also cause a pre-EE and DE forecast to look disconnected to the most recent historical actuals, which include realized EE and DE.

Figure 1 demonstrates this difference by showing a comparison of the 2014 IRP pre-EE and DE forecast to the historical load, adjusted to reflect the absence of historical EE and DE. APS will continue to utilize this basic framework for displaying its load forecasts, but will add more clarifying language around these differences in its next report.

Figure 1



While Figure 1 demonstrates that the forecast is more in line with history than previously presented, it is clear that, looking back at the 2012 IRP forecast, the 2012 IRP forecast was indeed too high. The principal reason for this was the expectation of stronger economic and population growth following the 2008 recession than actually occurred. To address this issue, APS is planning to adopt a new model of population growth, specifically the net migration portion of population growth. This enhanced modeling approach is discussed in the next section.

2. Population Growth and Long-term Economic Outlook

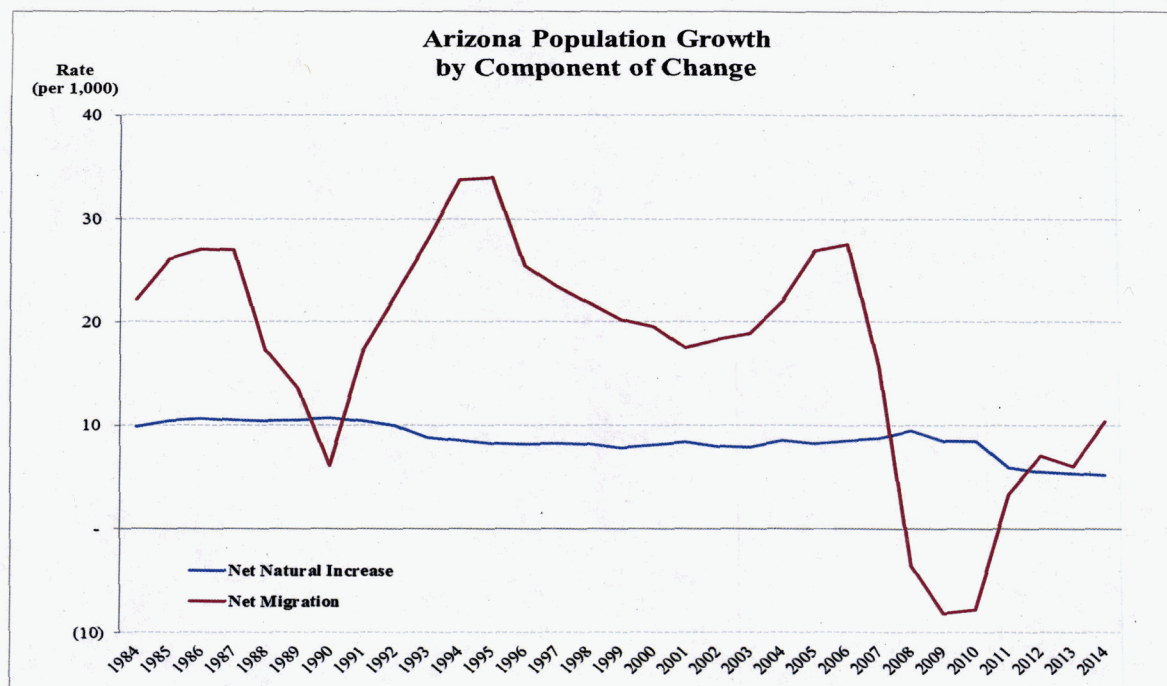
This section discusses the assumptions underlying the forecast for population growth, the long-term economic outlook, and the steps taken to provide a framework for developing such a forecast in the future. The population growth projection is the most important variable to be considered in developing a load forecast. Most of the other economic growth variables used in the development of different load forecast elements are directly

determined or highly influenced by the population growth forecast. The net migration component of the population growth assumption is sensitive to near-term business cycle effects, making it the most variable component. As discussed in more detail below, APS has contracted for the development of an econometric model that is designed to provide insights into changes in migration patterns based on the age and regional distribution of the population and relative business cycle impacts.

Growth in households and residential customers is largely determined by the rate of growth in the population, adjusted for the relatively stable trend downward in the number of persons-per-household. Changes in the labor force, employment, and occupied commercial and industrial floor space are evaluated on a per capita basis, and then multiplied by the population forecast to arrive at the final values used in developing the energy demand forecast. Likewise, total state real income and consumer spending are determined predominately by future population growth when looked at over sufficiently long periods of time (generally five years or longer – in the short run, business cycle effects can be more influential than the long-run population trend). As each of these variables is used, or at least considered, in the development of various elements of the load forecast, the extent to which the population projection underlies the trajectory of the projected load becomes apparent.

The current method for forecasting population growth relies on a separation of historical growth into two different, and largely unrelated, components: net natural increase and net migration. The net natural increase (NNI) is the amount of population added in each year due to the surplus of births in the state over deaths in the state. Net migration (NM) reflects each year's surplus of in-migration from residents of other states over the out-migration by Arizona residents to other states. Figure 2 shows total Arizona population growth historically broken down into these two components and expressed as a rate per 1,000 people.

Figure 2



From this figure, two prominent features of Arizona's population growth can be observed. First, the growth related to the NNI is stable from year to year and over many years. This shows that trends in fertility and mortality change gradually and therefore are largely predictable. Second, the pattern of NM is highly volatile and closely correlated with the overall business cycle in both Arizona and the nation as a whole. It has been APS's experience that sudden changes in NM have been among the most difficult forecast elements to predict. As the national economy emerged from the most recent recession, one of the main tasks of the APS load forecast was to anticipate the timing of when the Arizona housing market would be sufficiently recovered such that it could support new construction and return the area to a period of sustained growth. (In the prior two recoveries, the APS forecast tended to under-forecast the recovery, and actual customer growth and load growth both outpaced the forecast for several years.) Despite APS's historical experience forecasting economic recovery, it is clear that the 2012 IRP forecasted a stronger recovery than what actually emerged in 2012-2014.

In an effort to enhance the modeling and development of the NM forecast, APS has contracted with the Economic and Business Research Center (EBRC) at the University of Arizona to construct more formal statistical models of migration to ensure that fundamental shifts in migration patterns and behavior are made more transparent and useful in future projections. The models will be designed to capture both in-migration and out-migration flows separately and control for differences in the age of migrants as well as the regions from which they are arriving or to which they are moving. It is expected that these models will reveal whether any significant and permanent shifts have occurred in migration patterns for two of the most important sources of in-migrants: young people in their first decade in the work force and retirees. These models are scheduled for completion in the fall of 2015.

3. Modeling Techniques for Residential Use per Customer Forecasting

When APS reviews its modeling techniques for residential energy use per customer, it tests a variety of models and the evaluation criteria are described in this section. Based on its reviews, APS will continue to utilize its existing end-use model for residential demand forecasting. General industry practice provides for residential energy demand to be forecast using either least squares regression/econometric models or more detailed appliance-specific end-use modeling. APS currently uses the end-use model because of the insight gained in how appliances are used across most residences, and a lack of confidence in the forecast results of the tested econometric models.

The forecast of use per customer in the residential class is one of the key forecast elements used to create the overall load forecast, and APS reviewed its forecasting techniques related to this element even though use per customer has not been a source of significant variance. APS has historically utilized practical methods to gain insight into how residential customers use electricity in their homes. For most of the 1980s and 1990s, APS tested and used a variety of econometric models to explain historical usage patterns and project those patterns into the future. Beginning in the late 1990s, and especially following the national recession and the California energy crisis in 2001, the relationships developed by these

econometric models began to collapse. This prompted APS to review its technique and ultimately adopt an alternate forecasting technique that required a more discrete forecast of the electricity use of individual end-uses in homes. This end-use modeling approach has remained as the basis for the residential use per customer forecast since then. As good business practice, APS periodically re-estimates econometric models as potential alternates. This year's re-evaluation is described here.

The econometric models evaluated by APS typically include different measures of the following variables:

1. Weather. The weather variable typically includes cooling and heating degree-day data (CDDs and HDDs, respectively) as well as average humidity levels. Other weather measures that have been tested include CDDs interacted with humidity and HDDs and CDDs interacted with an index of air conditioner efficiency.
2. Economic conditions. Typically, a measure of household income is included as a variable to show the impact of rising incomes on electricity use over time. Income can be measured directly as income, or as a proxy such as retail sales or consumer spending, or as a more direct measure of wealth such as average home size. These variables are always expressed in real (inflation-adjusted) terms.
3. Electricity price. Price is typically measured as the average class-level price, adjusted for inflation.
4. Naturally-occurring efficiency. The impact of changing efficiency standards for major household appliances can take many years to fully roll through the stock of appliances in use at residential homes at any given time. It is important to reflect these known changes in both the history and the forecast. Appliances can be long-lived, so a change in standards can take as many as twenty years or more to be fully-embedded in the stock of appliances in use at any given time. APS has focused on two of the largest energy-using appliances in residential homes, central air conditioners/heat pumps and refrigerators, which have also been the target of major efficiency improvements since the late 1980s.

Six different models were tested in this evaluation. The models were evaluated based on their goodness of fit statistics (adjusted R-squared, F-statistic), how well each of the parameters performed (t-statistic, magnitude and direction of coefficient), and an analysis of where the largest residuals occurred and whether that had implications for the forecast "jumping-off" point. In particular, the ability to forecast out-of-sample was a key determinant in selecting the best models. Table 1 in the appendix displays the results for each model.

To compare these econometric models to the end-use model, the statistical results were used to calculate and forecast the energy load growth of residential customers over the past 15 years. This profile was then compared to the actual load growth and to what was originally predicted utilizing the end use model. It was found that the econometric models performed well in times of economic growth; however, the model did not perform well during economic recessions. Further, testing the econometric forecast models against reasonable expectations of current load growth produces a starting point in the forecast period that is inconsistent with recent observed growth rates. The end use model does not

suffer from these same problems. To conclude, at present the residential end-use model remains the preferred modeling tool for developing projections of residential use per customer, primarily because the current method has not suffered from any serious deficiencies and none of the other alternatives appear to be better. APS will continue testing alternate approaches to forecasting residential use per customer in the future as part of its good business practice.

4. Modeling Techniques for Commercial and Industrial Energy Demand Forecasting

The method used for forecasting electricity demand by C&I customers is different than the method used for residential electricity demand. Whereas end-use modeling is quite practical for forecasting residential demand due to the commonality of appliances in use across most residences and the similarity with which they are used, the business sector has a much higher degree of heterogeneity in both building types and end uses employed across the sector. These factors make end-use modeling for C&I customers much more difficult and expensive, and due to the large number of small-size samples required, more uncertain to implement. In contrast, econometric models are still the preferred method because they are easily developed and cost-effective. The forecast of C&I electricity demand accounts for almost half of APS's expected future demand, and the methods used to develop the projections warrant continual review as a good business practice. A variety of models were tested and the evaluation criteria are described in this section.

The econometric models utilized by APS typically include different measures of the following variables:

1. Weather. The weather variable typically includes cooling and heating degree-day data (CDDs and HDDs, respectively) as well as average humidity levels. Other weather measures that have been tested include CDD interacted with humidity, CDD interacted with occupied floor space, and HDD interacted with occupied floor space.
2. Economic activity. Typically a measure of overall economic activity is included as a variable to show the impact of a growing economy on electricity use over time. Economic activity can be measured directly as income, or as a proxy such as jobs, or as a more direct measure of demand-specific factors such as occupied floor space in commercial and industrial buildings. These variables are always expressed in real (inflation-adjusted) terms.
3. Electricity price. Price is typically measured as the average class-level price, adjusted for inflation.

Five different models were tested in this evaluation and, similar to the residential model tests, the models were evaluated based on the following: goodness of fit statistics (adjusted R-squared, F-statistic), how well each of the parameters performed (t-statistic, magnitude and direction of coefficient), and an analysis of where the largest residuals occurred and whether that had implications for the forecast jumping-off point. In particular, the ability to

forecast out-of-sample was a key determinant in selecting the best models. Table 2 in the appendix displays the results for each model.

This assessment found that the model in use for the last several years continues to be the preferred method. APS will periodically re-estimate these models as part of good business practice, and may incorporate other variables or techniques as they become known and available.

Conclusion

As required in Decision No. 75068, APS has re-examined its load forecasting techniques, primarily focusing on the components which have the largest impact on overall load growth. These components are the population growth forecast (and by extension, the residential customer growth forecast), the residential use per customer forecast, and the C&I customer electricity demand forecast. As part of good business practice, APS periodically re-examines its load forecasting techniques. Based on this year's re-evaluation, APS is developing a new econometric model designed to provide clearer insights into changes in population migration patterns. The models discussed here will be the basis for APS's load forecast in its next IRP.

Appendix

Table 1
Regression Results from Residential Usage Models

	Model A	Model B	Model C	Model D	Model E	Model F
HDD						
Estimate	0.56326	0.55726	0.55818			
t-stat	11.13	11	11.1			
HumCDD						
Estimate	0.71296	0.71235	0.71238			
t-stat	79.05	78.95	79.54			
Real WS PC						
Estimate	488.29199		0.0153			
t-stat	5.96		2.75			
RealRetailSales PC						
Estimate		0.01712				
t-stat		2.1				
ACEffIndex						
Estimate	-271.67083	-477.87873	-285.4467			
t-stat	-4.28	-5.26	-4.5			
HDDACEff **						
Estimate				0.35815	0.35874	0.36009
t-stat				11.09	11.11	11.18
HUMCDDACEff **						
Estimate				0.43161	0.4316	0.43179
t-stat				73.95	74.05	74.2
RefrIndexsqft						
Estimate				-265.28978	-209.37635	-216.72428
t-stat				-4.9	-6.63	-7.16
APSPPrice						
Estimate		-25.24261	-17.536	-0.00601	-0.00405	
t-stat		-3.38	-2.04	-1.39	-0.83	
RealWSPCIndexSQFT						
Estimate					221.78924	295.56151
t-stat					1.66	2.98
RealRetailSalesPCIndexSqFT						
Estimate				137.65808		
t-stat				1.48		
	<u>Model Notes</u>	<u>Model Notes</u>	<u>Model Notes</u>	<u>Model Notes</u>	<u>Model Notes</u>	<u>Model Notes</u>
Dependent Variable	Usage Adjusted for DE EE	Usage Adjusted for DE EE	Usage Adjusted for DE EE	Usage Adjusted for DE EE, by Square Feet	Usage Adjusted for DE EE, by Square Feet	Usage Adjusted for DE EE, by Square Feet
Adj R ²	0.9734	0.9734	0.9744	0.9694	0.9695	0.9695
F Value	1968.07	1575.09	1598.96	1363.11	1366.63	1710.96
Root MSE	65.4698	65.46108	64.9833	0.03886	0.03881	0.03878

Variable Name	Variable Definition
HDD	Billing Month HDD 65° F Index
HumCDD	Billing Month CDD 80° F * Natural Log Billing Month Humidity Index
Real WS PC	Real AZ Wage & Salary Per Capita Index
RealRetailSales PC	Real AZ Retail Sales Including Bar & Restaurant Sales Per Capita
ACEffIndex	Air Conditioning Efficiency Index with Base Year 2000
HDDACEff	(Billing Month HDD 65° F) / (AC Efficiency Index with Base Year 2000)
HUMCDDACEff	(Billing Month CDD 80° F * Natural Log Billing Month Humidity) / (AC Efficiency Index with Base Year 2000)
RefrIndexsqft	(Refrigerator Efficiency Index with Base Year 2000) / (Average Home Size in Square Feet)
RealWSPCIndexSQFT	(Real AZ Wage & Salary Per Capita Income Index with Base Year 2000) / (Average Home Size in Square Feet)
RealRetailSalesPCIndexSqFT	(Real Retail Sales with base year 2000) / (Average Home Size in square feet)
APSPPrice	Revenue Sales or average effective price in US cents indexed to year 2000.

Table 2

Regression Results from Commercial Usage Models

	Model A	Model B	Model C	Model D	Model E
HDD					
Estimate	239.8				250.9
t-stat	7.6				38.1
HDDSpC					
Estimate		0.00047	0.00047	0.00052	
t-stat		9.0	9.1	10.4	
CDDHum					
Estimate	117.3				119.2
t-stat	45.0				38.1
CDDHumSpC					
Estimate		0.00023	0.00023	0.00024	
t-stat		52.5	53.1	53.2	
RealAPSPPrice					
Estimate	(1,387.8)				4,928.3
t-stat	(2.0)				6.9
RealAPSPPriceSpC					
Estimate		(0.00457)	(0.00381)	(0.00190)	
t-stat		(3.8)	(3.1)	(1.5)	
TuOcpFtrSpC					
Estimate	3.2				
t-stat	31.3				
IndOcpFtrSpC					
Estimate		2.1	2.0	1.6	
t-stat		18.5	15.2	11.5	
IndProd					
Estimate			1,354.1		
t-stat			2.4		
RetailSls					
Estimate				0.02579	
t-stat				5.2	
TuNFJ					
Estimate					622.3
t-stat					24.9
	<u>Model Notes</u>	<u>Model Notes</u>	<u>Model Notes</u>	<u>Model Notes</u>	<u>Model Notes</u>
Dependent Variable	Usage Adjusted for DE/EE	Usage Adjusted for DE/EE	Usage Adjusted for DE/EE	Usage Adjusted for DE/EE	Usage Adjusted for DE/EE
Adj R ²	0.96	0.97	0.97	0.97	0.94
F Value	1,074	1,466	1,203	1,340	732
Root MSE	36,520	31,440	31,061	29,472	43,808

Variable Name	Variable Definition
HDD	Billing Month HDD 65° F
HDDSpC	Billing Month HDD 65° F * Total (Office/Retail/Industrial) Occupied Floor Space
CDDHum	Billing Month CDD 65° F * Natural Log Billing Month Humidity
CDDHumSpC	Billing Month CDD 65° F * NL Billing Month Humidity * Total (Office/Retail/Industrial) Occupied Floor Space
RealAPSPPrice	Real APS Price
RealAPSPPriceSpC	Real APS Price * Total (Office/Retail/Industrial) Occupied Floor Space
TuOcpFtrSpC	Maricopa County Total (Office/Retail) Occupied Floor Space
IndOcpFtrSpC	Maricopa County Office/Retail/Industrial Occupied Floor Space
IndProd	US Industrial Production Index (SA)
TuNFJ	Total Arizona non farm jobs (SA)
RetailSls	Arizona Taxable Retail Sales (NSA)